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Draft Pond Management Principles

Introduction:

There are seven great ponds located on Nantucket; Hummock, Long, Sesachacha, Miacomet, Coskata, Gibbs and Tom Nevers. Nantucket's ponds vary in geology, chemistry, biology and historic management. The Town of Nantucket has actively participated in monitoring four of these seven ponds; Hummock, Long, Sesachacha and Miacomet, whereas the other three systems fall within private lands and are therefore managed privately. The natural progression of pond systems over hundreds of years is to fill in with organic matter from plant decay, animal waste and sediment deposition. However, this natural progression is sped up through human activities. This process is termed "eutrophication" and it is part of the natural evolution of closed pond systems, however it is being accelerated by population growth and human activities. The development and subsequent use of synthetic fertilizers in the 20th century has increased the rate of eutrophication due to increased availability of usable nutrients. Ponds are subjected to nutrient inputs from improperly cited septic systems influencing groundwater nutrient concentrations, fertilized lawns abutting water bodies and fertilizers leaching into groundwater, paved roads, illegal de-watering activities and mowed entry points diverting storm water towards ponds and enhanced atmospheric nutrient concentrations in rain from the burning of fossil fuels. Nutrient additions to aquatic systems cause shifts in biological processes that can result in habitat degradation. Effects include excessive algae and seaweed growth, which in turn lead to reduced water clarity and eventually organic matter enrichment in water and sediments. This has the concomitant effect of increased rates of oxygen consumption and periodic depletion of dissolved oxygen, especially in bottom waters, as well as limiting the growth of desirable species capable of producing toxins in some cases. Even without changes to water clarity and bottom water dissolved oxygen, the increased organic matter deposition to the sediments generally result in a declining habitat quality for benthic infauna communities (animals living in the sediments). These habitat changes induce a shift from high diversity deep burrowing animals (which include economically important species), to low diversity shallow dwelling animals (indicative of degraded habitat). This shift causes significant degradation of resources and a loss of productivity to shell-fishing, sport-fishing and offshore fisheries. Both the sport-fishery and the offshore fin fishery are dependent upon highly productive coastal salt ponds as a habitat and food resource during migration and various stages of their life cycles. Sea level rise and extreme weather events will play an important role in the future management of these pond systems, as over-wash events will become more prevalent jeopardizing coastal infrastructure as evidenced with Sesachacha Pond during the winter of 2018.

Each of Nantucket's ponds have undergone rigorous scientific investigations by a multitude of researchers from the 1970's to present (earliest reports are from 1910 Survey of inland waters). Hummock, Sesachacha and Long Ponds have had Massachusetts Estuaries Project (MEP) studies conducted which combined habitat assessments, long-term historic water quality data, hydrodynamics and watershed land use to develop threshold nutrient concentrations. The MEP reports and resulting goals (TMDL's: Total Maximum Daily Loads) are nitrogen based, because at the time of the original MEP designations each of the pond nutrient ratios indicated nitrogen was the limiting nutrient (availability of usable nitrogen limits growth of algae). MEP nitrogen thresholds were developed specifically for each system such that historic habitat should recover if the threshold nutrient concentrations were achieved. Given the time elapsed since these studies, changes to zoning and land use should be considered and updated periodically to assess whether historic 'build-out' conditions have since been achieved or surpassed, warranting the need for updated linked-embayment model runs to support nutrient reductions. Primary sources of nitrogen are atmospheric deposition, wastewater, fertilizers, and changes in the freshwater hydrology associated with development (storm water). Typically, systems with large surface areas, are more influenced by atmospheric deposition, due the area subject to deposition (Sesachacha), whereas small systems tend to be influenced less by atmospheric nitrogen deposition (Long). Streams and direct wet and dry deposition from the atmosphere represent natural sources of nutrients, however these are inevitably affected by human activities as well, such as proximity to fertilized landscapes, agriculture and failed septic systems. Phosphorus is the limiting nutrient in freshwater systems and an important driver of harmful algal blooms of cyanobacteria (CyanoHAB) in Nantucket's great ponds. Phosphorus comes from past detergent use, the weathering of rocks, streams, wastewater and fertilizer. Recent reports indicate co-limitation between nitrogen and phosphorus is likely in brackish coastal water bodies[1]. Due to declining salinity in Hummock Pond and fresh water conditions in Miacomet Pond, The Town of Nantucket submitted and received a grant from the Massachusetts Department of Environmental Protection (MaDEP) to assess the inputs and potential influence of phosphorus in each pond. The project, conducted by Dr. Ken Wagner of Water Resources Services LLC, entitled "604b Study of Phosphorus Sources to Hummock and Miacomet Ponds" was a collaboration between the Nantucket Pond Coalition, the Nantucket Land Council and the Town of Nantucket[2]. The Nantucket Pond Coalition has been instrumental in Nantucket pond research and protection over the years. This study as well as historic studies provide ample background information on Nantucket's ponds and set the stage for future research and management decisions.

These management principles were developed in accordance with the "Final Generic Environmental Impact Report: Eutrophication and Aquatic Plant Management in Massachusetts" henceforth referred to as 'the management guide', prepared by the Executive Office of Environmental Affairs, Commonwealth of Massachusetts, 2004[3]. Cost estimates for each management option are provided for comparison however project values may be higher due to permitting requirements, Nantucket's remote location and the need for equipment and supplies to be shipped here from off-island. Long-term watershed management techniques are considered optimal because they eliminate or reduce the source of nutrients and educate the public on their role in nutrient pollution. However, many pond systems require in-pond management to control internal nutrient loading, combat nuisance pond weeds and to control cyanobacteria blooms, which pose a threat to public health. These management principles address long-term and short-term management goals related to the Natural Resources Department mission to "**preserve, protect or restore Nantucket's natural resources through responsible active**

management, research, education and outreach". As such, it is important to keep in mind that projects will require monitoring as part of their permit requirements and maintenance to ensure long-term success and project efficacy. The outline of each pond follows the sections described in 'the management guide' and is broken into;

I. Statement of Problem
II. Management Goals
III. Watershed/ Pond Characteristics
IV. Review of Past In-pond Management Techniques
V. Review of Existing Watershed Management Techniques
VI. Evaluation of In-pond and Watershed Management Alternatives
VII. Management Recommendations

Nutrient management can fall into the following categories[2];

- Point Source Management – control of point sources, usually piped discharges Non-Point Source Management – control of diffuse nutrient sources from the watershed
- Hydraulic Controls – diversion, dilution, flushing, and hypolimnetic withdrawal strategies
- Phosphorus Inactivation – chemical binding of phosphorus to limit availability
- Dredging – removal of nutrient-laden sediments
- Removal of Bottom Feeding Fish – elimination of major recyclers of nutrients
- Artificial Circulation and Aeration – mixing and oxygen addition*
- Bacterial Additives – encouraging uptake of nutrients by non-algal microbes*

*Although, not discussed in detail within these principles, artificial circulation would require a network of points by which artificial aeration would be necessary, and the expense and interference of the application network with recreational and ecological functions is generally intolerable, so this approach is unlikely to be appropriate for these ponds[2]. Bacterial additives are also not likely to produce the desired effect in Nantucket's ponds until nutrients, cyanoHAB and aquatic vegetation is more actively controlled. Therefore, although Aeration and Bacterial Additives represent two nutrient management alternatives, they are less likely to be employed on Nantucket due to the circulation patterns and current level of nutrient impairment observed.

Works Cited

1. Conley et al. 2002. *Science*, Vol. 323. Controlling Eutrophication: Nitrogen and Phosphorus.
2. Wagner K. Water Resource Services Inc. (2017). 604b Study of phosphorus sources to Hummock and Miacomet Ponds Final Report
3. Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. 2004. Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report. Edited by Kenneth J. Wagner. Department of Environmental Protection and Department of Conservation and Recreation, Executive Office of Environmental Affairs, Commonwealth of Massachusetts.

Pond Opening History

Nantucket Ponds have been being managed since Native Americans and early settlers connected Long Pond to Hither Creek via a ditch in 1665[1]. Early accounts of Hummock and Miacomet Pond openings date back to the mid 1800's, while the first accounts of Sesachacha openings were from the late 1800's. From the earliest accounts, ponds were opened to ensure a year-round food and bait supply. However, as early as 1920 there were accounts of elevated groundwater interfering with farming practices in the Sesachacha watershed area. The historic process of getting a pond opened was to petition the Board of Selectmen. From the historic newspaper articles, it appears that Hummock and Miacomet may have been opened more regularly for both fish passage and flooding issues, while Sesachacha openings were more spread out. In the early 1900's Sesachacha went ten years without being opened and when it was opened the wind closed it prematurely. From the time of the earliest settlers, up until the early 1970's pond openings were a regular practice, which had both proponents (fishermen and homeowners experiencing flooding) and opponents (farmers who used the ponds for irrigation). In the late 1960's and early 1970's the pond openings allowed for cattail removal and excavation work to be performed around the pond edges. As early as 1973 Conservation Commission reports warned of issues due to increased development; "We are at a critical point in Nantucket's history. Our actions **now** will determine whether the islands natural resources will be protected for the enjoyment of future generations or will be destroyed by overdevelopment." In the late 1970's The Norwood Farm Trust submitted an NOI to dredge the upper portion of Miacomet Pond. There were concerns over the loss of swamplands and habitat by the Conservation Commission but by 1981 the area had been dredged and all the water drained into the main body of the pond. This caused the Conservation Commission to discontinue the NOI until the upper portion had been restored. In the early 1980's pond openings ceased due to Wetlands Protection Act regulations. Coastal Geologist Jeff Benoit of the Executive Office of Environmental Affairs felt that "opening the pond was not consistent with the mandates set forth by the Coastal Regulations of the Wetlands Protection Act of 1978". Town meeting Article 67- Local Control of Pond Openings passed in 1993 and a Home Rule petition was issued to Nantucket, allowing the Town to open the great ponds without State or Local permits. The Town was still required to receive permission from the Army Corps of Engineers each time the ponds were opened. In 1993, Sesachacha Pond was opened for the first time in over ten years. From 1995 to present both Hummock and Sesachacha Ponds were opened twice per year in the Spring and Fall to facilitate fish passage. Due to protected species habitat, the openings must occur between April 1 and April 30 in Hummock Pond and between April 1 and April 15 in Sesachacha Pond. Depending on water temperature, the openings may not occur when fish are present to take advantage of the brief opened window to enter/ exit the ponds to spawn. Miacomet Pond was opened less frequently over the same 1995 to present timeframe. The reasons for not regularly opening Miacomet in the same fashion as the other ponds were; the excessive watershed contribution of freshwater due to excessively drain soils and impacts to flora and fauna. In 1996, the siphon pump system that was purchased to drain the pond during periods of flooding failed due to precipitation and groundwater levels. The historic failed attempts at draining Miacomet watershed of its elevated groundwater underline the limited benefit that opening or draining the system has on groundwater levels. Well elevation reports from 2003 indicate that wells in the Island variety parking lot (off lower Liberty St) did not decrease as a result of the 2003 illegal opening which lowered the pond level by 8.75ft. According to the 2000 Town Biologist report on Miacomet Pond, "Development has altered two natural processes (1) nitrogen/phosphorus cycles and (2) flooding. Development has increased nitrogen and phosphorus concentration in surface and groundwater flows. Housing densities inhibit the percolation of precipitation; increase sedimentation and erosion; increase surface runoff volume". Flooding issues in the Miacomet Pond Watershed are a result of high groundwater elevations combined with inhibition of water percolation due to development and historic watershed manipulation. The scientific investigations performed to date do not warrant openings of Miacomet Pond in the same manner as Hummock and Sesachacha, however flooding issues must be mitigated by addressing public and private storm water infrastructure and future development of this watershed.

Inevitably, switching these ponds between brackish and freshwater over the last few centuries has influenced the way in which nutrients are cycled. However, it is important to note that in primarily closed systems such as these ponds, nutrients do not go away, they build up and feed further algal growth which then contributes decayed material to the sediment, slowly shallowing the systems until they eventually, over the course of hundreds of years, turn back into a wetland. This is the natural progression of pond systems even without anthropogenic (human) influences. Once you add anthropogenic loads due to the atmosphere, wastewater, fertilizer and storm water; you accelerate the process by which ponds eventually become wetlands. The principles suggested within this document include both watershed management as well as in-pond management to improve the health and usability of Nantucket's ponds.

Works Cited

1. Sesachacha & Sankaty: Pond opening and erosion on Nantucket's eastern shore by Wesley N. Tiffney, Jr and Clinton Andrews. Historic Nantucket, *Vol 38 no. 1 (Spring 1990), p. 4-6.*
2. Inquirer and Mirror Archived Articles
http://digital.olivesoftware.com/Olive/APA/Nantucket/default.aspx#panel=home
3. Conservation Commission and Town Biologist reports- copies available at Natural Resources office.

Hummock Pond

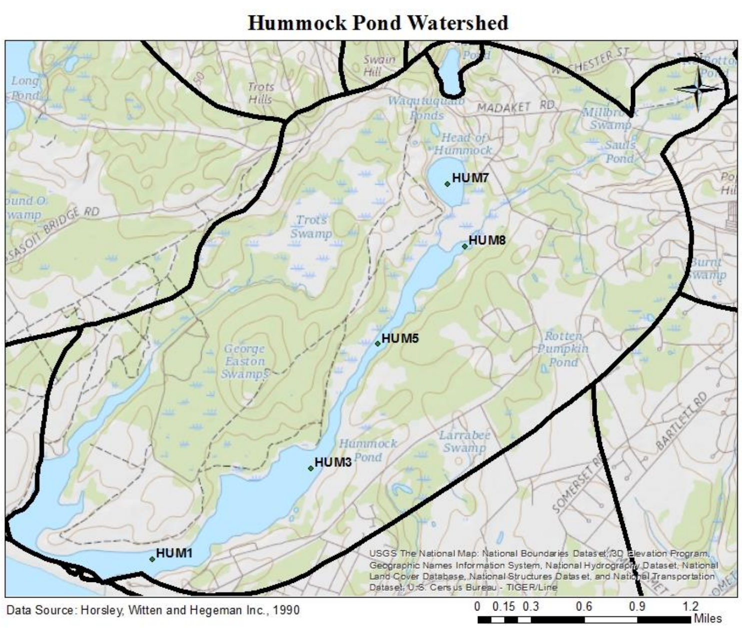

Figure 1. Extent of Hummock Pond watershed, as determined by Horsley, Witten and Hegeman in the 1990 Nantucket Water Resources Management Plan. Location of water quality sites used for Massachusetts Estuaries Project and ongoing sampling.

I. Statement of Problem

Hummock Pond is a coastal pond located on the southern shore of Nantucket, Massachusetts. The pond is generally closed to exchange with the Atlantic Ocean except for bi-annual pond openings which occur in the spring and fall to enhance anadromous/ diadromous fishery resources. The groundwater + surface water contributing area is 2227 acres, while the pond surface area varies from 140 to 425 acres depending on the amount of precipitation. The watershed to pond ratio is therefore between about 5:1 and 15:1, depending on the season. The primary ecological threat to Hummock Pond as a natural resource is degradation resulting from nutrient enrichment. Although the watershed and the pond have experienced issues relative to bacterial contamination, this does not appear to be having large ecosystem-wide impacts. Development in the Hummock Pond watershed is limited compared to Miacomet Pond, due to the entire western shore being comprised of conservation land which was historically used for agriculture. Hummock Pond and its associated watershed have been significantly altered by human activities over the past ~100 years[1]. As a result, the present nitrogen "overloading" appears to result partly from alterations to its ecological systems. These watershed alterations subsequently impact nitrogen loading within the watershed and influence the degree to which nitrogen loads impact the estuary[1]. Reports dating back to 1989 indicated that the primary bloom forming algae was *Anabaena*. *Anabaena* has since undergone a phylogenic name change to *Dolichospermum,* which is the type of algae which bloomed in Hummock Pond in 2016 and 2017.

Hummock Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards not being met due to low water clarity (<1.2 meter: safe swimming standard), nuisance pond weed and potentially harmful cyanoHAB. Water quality standards not being met due to high Total Phosphorus (TP) and high Total Nitrogen (TN). TN exceeded the goal of 0.500 mg/L, with 2016 pond-wide averages of 0.825 mg/L. Hummock phosphorus exceeded EPA water quality standards of 0.015 mg/L, with pond-wide averages of 0.0325 mg/L. Recent 604b work indicated that TP levels >0.02 mg/L represent a distinct algae bloom hazard, while 2016 Hummock TP levels were 0.080 mg/L. The research conducted as part of the 604b study indicated that sediment provides additional phosphorus for algal blooms and removal may alleviate not only nutrients capable of inducing blooms, but also resting algal cysts which lay dormant in the sediment. Historically, algae blooms in Hummock Pond would originate in the Head of Hummock and eventually make their way to the main pond basin. However, blooms in 2016 and 2017 began in the main upper portion of the pond and continued throughout the summer season, indicating further degradation of the pond habitat. The chlorophyll data from the Head of Hummock region indicates restriction between the upper main pond and Head of Hummock, since high dissolved oxygen concentrations associated with the algae blooms were observed in 2016, while subsequent bottom oxygen depletion was likely post bloom conditions. Aesthetic values and boating are limited due to dense submerged aquatic vegetation, cyanoHAB and invasive phragmites. There is a need for defined access and an information kiosk describing bloom possibility and any other pertinent information to the pond. Historically the Head of Hummock Pond was separate from the main pond basin and there have been discussions with the MaDEP regarding the isolation of the Head of Hummock from the main pond due to concern over the elevated concentrations of sediment derived phosphorus as evidenced through the 604b phosphorus study.

II. Management Goals

	Total Nitrogen	Phosph-orus	Total Phosphorus	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
Goals	0.500 mg/L	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

III. Watershed/ Pond Characteristics

According to the Hummock Pond MEP report[1], much of the locally controllable, un-attenuated nitrogen load to Hummock Pond is from wastewater at 81%, while impervious surfaces, farm animals and fertilizer all contribute less than 7% each respectively. Most of the uncontrollable nitrogen load to Hummock Pond is from direct precipitation to the water body surface area at 15%, while natural surfaces in the form of small streams contribute 5%.

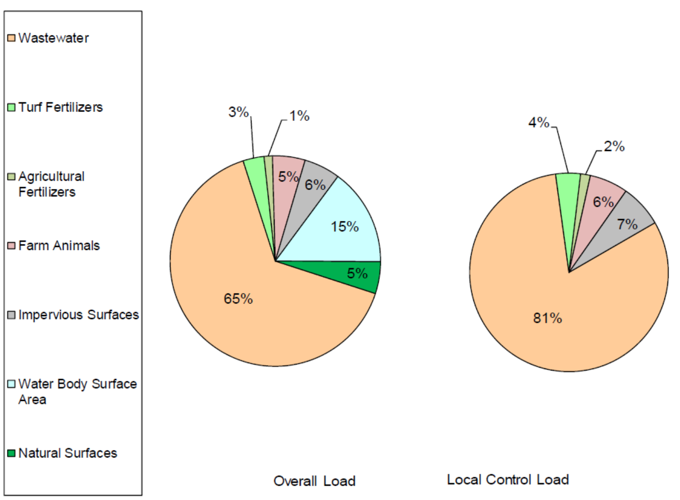

Figure IV-3. Land use-specific unattenuated nitrogen load (by percent) to the overall Hummock Pond System watershed. "Overall Load" is the total nitrogen input within the watershed, while the "Local Control Load" represents those nitrogen sources that could potentially be under local regulatory control.

Pond-wide Total Nitrogen (TN) in 1989 averaged 1.09 mg/L while Total Phosphorus (TP) averaged 0.343 mg/L[2]. The conductivity averaged 376ms/cm (or <0.2 psu parts salinity units) in 1989, 8 years after the 1984 April opening which lasted 3 days. Average pond-wide salinity averaged 6.62 psu in 2016 and continues to be highly dependent on the duration of the pond openings. Currently, the pond is highly eutrophic and experiencing significant impairment[1]. Current conditions show improvement over 1989 concentrations, however are elevated over the MEP historic (2005/2007) TN average of 0.691 mg/L. In 2016, pond-wide TN averaged 0.825 mg/L, elevated concentrations (0.870 mg/L) were observed at HUM5 located approximately halfway up the pond. TP measured as part of the pre-pond opening sampling, revealed elevated values of 0.053 mg/L, nearly four times the 'healthy' threshold of 0.015mg/L. Average 2016 summer pond-wide phosphate was 0.0325 mg/L, and was greatest in the northernmost channel of the pond.

According to the 604b study[3], phosphorus loading to Hummock Pond was estimated to be 399 kg P/yr, with about 75% from internal loading from sediments. Dr. Wagner concluded that N, P and light are important drivers of phytoplankton growth in Hummock Pond and that available phosphorus concentrations can support cyanobacterial blooms. Because the bloom forming alga *Dolichospermum* is capable of fixing nitrogen from the atmosphere it is likely controlled by phosphorus availability within the pond. The 604b study concludes that, "If internal phosphorus loading could be controlled in Hummock Pond, no further action should be necessary to prevent the frequent and severe cyanobacteria blooms currently experienced during summer. Additional watershed management would be desirable mainly as protection to prolong the benefits of internal load control[3]".

IV. Review of Past In-pond Management Techniques

Aquatic Vegetation Management

The Nantucket Pond Coalition has facilitated aquatic harvesting of rooted plants from Hummock Pond and has plans to mitigate Phragmites along Hummock Pond in 2018. According to Dr. Wagner, "harvesting represents the primary alternative strategy, and has already been demonstrated in Hummock Pond in 2015. Mechanical harvesting machines, functionally aquatic lawnmowers, can be used to keep boating, swimming and fishing lanes open, creating a network of channels and open patches that are both ecologically and recreationally beneficial".

- **2015:** The 2015 harvester pilot project in Hummock Pond removed 23,000 lbs of aquatic vegetation which was re-cycled as fertilizer by Sustainable Nantucket.
- **2017:** Aquatic vegetation removal continued in 2017.
- **2018:** Submerged aquatic vegetation removal will not continue in 2018, however a five-year Eastern shore phragmites mitigation project will begin on August 28, 2018.

Hydraulic Control

Bi-annual pond openings represent a hydraulic management technique and facilitate dilution of high-nutrient pond waters with low-nutrient ocean waters. However, depending on the duration of the openings, this exchange can cause groundwater with elevated nutrients to be drawn into the pond at a faster rate than without the openings. During flooded conditions, the surface area of the pond increases from ~140 acres to approximately 425 acres[1]. Hummock Pond was historically opened to the ocean to enhance fish resources and relieve flooding. During the 1984 pond opening, P. Dunwiddle and J. Roe conducted a study on the efficacy of the openings[4]. The finding from this report indicated that the farthest region which experienced lowered water level was Millbrook swamp, there was no change in the mosquito breeding grounds in Trots swamp, salinity increased in the pond but was not measurable at the wells nearby, no saltwater fish were attracted to the opening, there were no impacts to nesting waterfowl, limited shoreline erosion was observed at two summer residences nearby, pond openings limit dune formation and effect aquatic and pond shoreline ecology. These findings are important for the current understanding of the perceived effect that pond openings have on the nearby groundwater table. Unfortunately, historic building practices did not consider the proximity of wetlands and the impact those wetlands would have on flooding in wet Spring months.

Concerns have been voiced over the efficacy of the pond openings, the impact to freshwater species and the subsequent enhanced groundwater flow that results from the sometimes-long duration pond openings which Hummock Pond experiences. While vigorous flushing of the pond occurs during inlet openings, pond water is continuously discharging to the ocean by pond water seepage through the barrier beach during closed conditions. In addition to historic openings to the ocean, past management activities included dredging a channel from the hyper-eutrophic Head of Hummock region to the main pond basin. Currently, further investigation is required to determine if isolation of the Head of Hummock is permittable, whether pond openings are providing sufficient flushing for in-pond fauna to thrive and the effect of pond openings on phosphorus availability. The efficacy and environmental benefit of pond openings has long been debated. The lower pond reveals post opening nutrient improvements while the upper pond may experience enhanced nutrient loads through groundwater inflows post closure. Given long-term watershed non-point source nutrient management, groundwater derived loads should decline. In addition, connection to town water and sewer systems will inevitably affect the quantity and quality of groundwater over time. Investigations into hydrological enhancements of pond openings revealed that openings should occur a few days prior to the spring tide, during the latter portion of the dropping offshore tidal stage, the hydraulic head differential (difference between ocean height and pond height) must be over 1 meter, preferably 1.5 meters at the time of the pond opening, and the use of offshore predictive wave models (Wavewatch III) will allow for the most successful opening[7]. It is important to note that with increased frequency and duration of extreme weather and sea level rise predicted, Hummock Pond will continue to periodically receive saline waters from the Atlantic Ocean. It has long been recommended through the Hummock Pond MEP and subsequent technical memos that pond openings represent a relatively inexpensive means to improve nutrient-related water quality within the pond[1,5,7]. However, given that sediment derived phosphorus is capable of driving potentially harmful cyanoHAB, periodic pond closures may be warranted to lower salinity and prepare for in-pond management of phosphorus.

Aeration

In response to the Cyanophyte blooms and hyper-eutrophic state of Head of Hummock Pond, the Nantucket Land Council funded a project whereby Community Preservation Act funding was used to test a SolarBee® long-distance water circulation device to circulate water and disrupt cyanophyte bloom development/ continuation[6]. Findings from the deployment are as follows:

> There was no clear evidence that the SolarBee® long-distance circulation unit had any effect on the 2011 water quality of HHP. Nutrient levels continued to be excessive during the mid-summer and fall and the Cyanophyte blooms continued unabated as in the two previous years with the algal neurotoxin, microcystin, detected in the water column on several occasions. In fact, summaries of water temperature data collected from different levels of the pond provided evidence that long-distance water circulation never became established in the epilimnion of the pond during 2011. It appears that ambient wind

blowing across the surface of the pond is sufficient to disrupt the integrity of long-distance water circulation generated by the SolarBee® unit[6].

V. Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. As such the Town of Nantucket has several long-term management techniques currently underway to protect Hummock Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
    - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
    - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
    - No applications of plant nutrients shall be made:
        - between December 1 and March 1;
        - to frozen and/or snow covered soil;
        - to saturated soil, or soils that are frequently flooded;
        - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more
        - targeted application method, such as a drop spreader;
        - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply
    - Non-point Source Management
        - Board of Health Regulations
            - Local Regulation 55.00 Inspection and Upgrading of Substandard Onsite Sewage Disposal Systems within the Hummock Pond Watershed Protection District. September 2010.
            - Local Regulation 56.00 Septic Wastewater Flow Limitations within Hummock Pond Watershed Protection District.
        - Comprehensive Wastewater Management Plan- State approved 20-year plan
            - Hummock Pond South: Design, 2022 Construction, 2023
            - Hummock Pond North: Design, 2025 Construction, 2026
        - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
        - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per

year and no phosphorus containing fertilizer may be used unless a soil test indicates a phosphorus deficiency.

- To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
- To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
- To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
- To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
- To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

VI. Evaluation of In-pond and Watershed Management Alternatives (Long-term)

- Update watershed inspection and upgrade timeline until sewer becomes available (BOH)
- Improve storm-water infiltration in watershed (remove direct sources of runoff from East side pathways/ Bartlett area, enhance infiltration and vegetated buffers) (DPW).
- Conduct survey of vegetation (follow Miacomet procedure) (NRD 2018).
- Assess soft sediment quantity through depth survey, following Ken Wagner's protocols (NRD 2018).
- Sediment removal to sandy bottom (Rough estimate from Miacomet investigation ~$8.1 million).
  - Pre-assess sediment quality using same procedures used in Miacomet Pond ($2000) for likelihood of disposal.
- Town owned excavation equipment to facilitate pond openings for emergency management and routine clearing of accumulated sediment from opening channel (Cat 320 Excavator: ~$300,000, Dredge: ~$500,000, Dump truck for transport to DPW: ~$210,000, Estimate of staff costs: No more than 40 hours per year excavation time, ~20 hrs of dump truck runs (@$27.50/hr=$1650) Approximate total= $822,650 (Excludes taxes/ shipping/ maintenance)
- In-pond bottom sediment provides additional phosphorus for algal blooms, 604b recommended phosphorus inactivation due to potentially toxic cyanobacterial blooms.
  - SOLitude estimates provided by The Nantucket Pond Coalition:
  - Low dose treatment= $100,000.
  - High Dose treatment = $525,000.
  - Trial: Head of Hummock only 17 acres= Low $18,500, High $75,000 (depends on area subject to anoxia).
  - Trial: Upper reaches (33 acres) + HOH (17 acres)= Low dose: $55,500. (Propose for Spring 2019).

- High dose= $225,000 (unlikely due to logistics of this much Aluminum chloride being transported to island).

- Investigate engineered solutions for flooding relief within watershed.
- Re-assess load from western shore which previously indicated elevated concentration of inorganic nitrogen (NLC 2018).
- Investigate algaecide utility
  - Must track the algae composition weekly and apply treatment prior to bloom but as algae is multiplying (PAK27: no water or sediment persistence, Captain XTR: 1-2 day half-life, can lead to low dissolved oxygen levels, toxic to fauna).
  - Permits required: Conservation Commission and BRP WM 04.
- Possibility for Permeable Reactive Barrier (PRB) if load is significant- ~$138,000 or $180/ft^2.
- Pilot project to harvest phragmites.
  - Recent studies in Martha's Vineyard have indicated that harvesting phragmites and pelletizing the harvested material represents a compromise by which both nutrient remediation and view-shed management can be achieved for relatively low costs compared with chemical techniques.

VII. Management Recommendations (short-term)

- Add Total Phosphorus (TP) to routine Hummock Pond monitoring program (NRD 2018).
- Assess soft sediment quantity through depth survey, following Ken Wagner's protocols (NRD 2018).
- For maximum phosphorus removal benefit, consider altering pond opening procedures prior to phosphorus inactivation to allow for freshening of water (Solitude/ NRD).
- Contract out Wetland Protection Act permitting for Conservation Commission NOI. (Solitude providing quote)
- Investigate need for further permitting to apply chemicals through DEP, possible need for 401Q Water Quality permit through DEP (Solitude).
- Request review by Natural Heritage Endangered Species Protection (NHESP) (further action required if protected species are present).
- Test treatment: 33 Acres in upper reaches of pond. (Quote requested- Estimate: $18,000 - $45,000 would be sufficient to control nutrients for the season, settle onto sediment and provide further sediment inactivation and reveal efficacy of this treatment option).

Works cited

1. Howes B.L., S. Kelley, E.M. Eichner, R.I. Samimy, D.R. Schlezinger J. Ramsey (2013). Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for Hummock Pond, Massachusetts. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

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Miacomet Pond

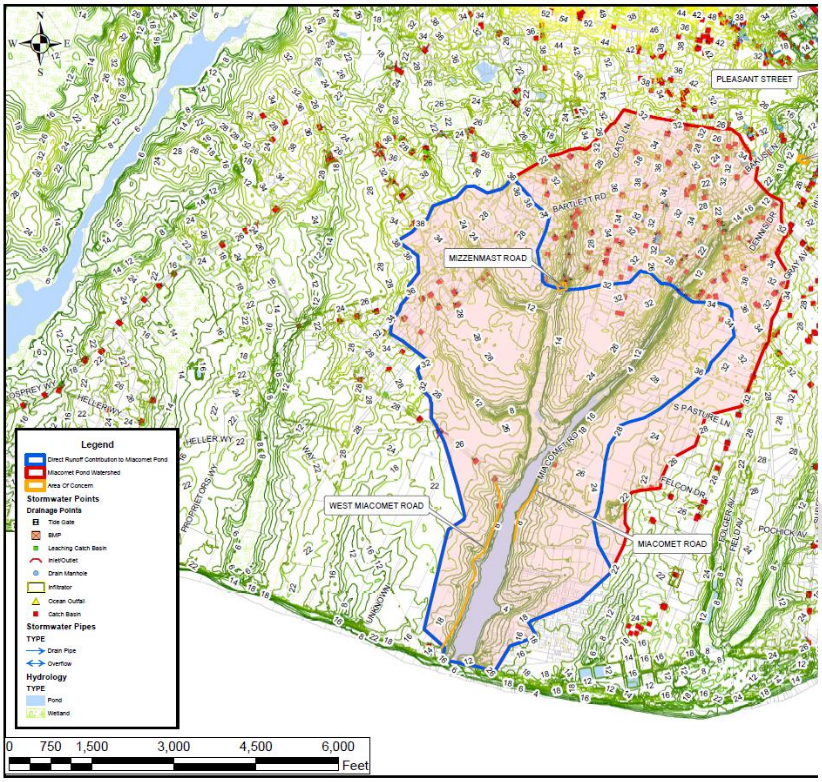


Figure 1. Woodard and Curran (2014) direct surface contribution to Miacomet Pond.

I. Statement of Problem

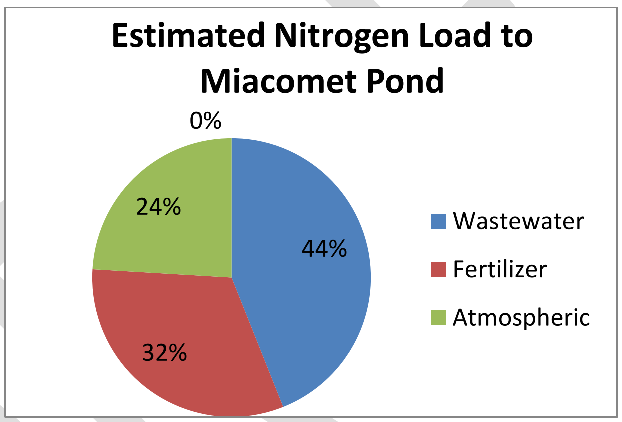
Miacomet Pond is a 43.5-acre pond with an average depth of 4.0 ft, located on the southern shore of Nantucket Island, MA[1]. Much of water inputs to the pond are derived from direct surface runoff (653 acres), while the remaining 387 acres of the watershed contribute to groundwater input through isolated depressions (Figure 1)[3]. The watershed that feeds Miacomet Pond is approximately 24 times the size of the pond itself, which can lead to flooding during wet seasons. This means that freshwater inputs dominate this pond[3]. Historically the pond was opened yearly to the Atlantic Ocean (Appendix- Draft Pond Opening and Modification History**)**. The pond periodically receives salt water from the ocean during periods of high sustained winds and was last physically opened to the ocean in 2005 due to flooding concerns. The first written records of pond status were from the 1910 Inland Waters reports, which included acidity-alkalinity, temperature, light penetration, dissolved oxygen, iron content, fish and vegetation presence. Miacomet Pond was given a moderate/ poor ecological health score in the report entitled “Overview of Nantucket Fresh Ponds: 1989-1992” due to its extreme salinity fluctuations, oxygen stress and elevated nutrient and phytoplankton concentrations[2]. Since then, several reports have been conducted on Miacomet Pond’s watershed, water quality, flora and fauna and hydrodynamics[3,4,5,6,7,8].

II. Management Goals

	Total Nitrogen	Phosph-orous	Total Phosphorus	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
Goals	(no regulatory threshold developed)	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

III. Watershed/ Pond Characteristics

According to the 2002 Miacomet study conducted by Applied Science Associates[5], wastewater accounted for 44% (1484kgN/yr) of the total load of nitrogen to the pond. Fertilizer was the second largest contributor at 32% (1080kgN/yr), while atmospheric deposition accounted for 24% (812 kgN/yr). It was estimated that the golf course contributed 23% to the total nitrogen load while residential lawns were estimated to contribute 9%[5].



Bioactive nitrogen (PON+nitrate+ammonia) in 1989 averaged 0.700 mg/L, however only one station located near MP2 was sampled. Phosphorus averaged 0.050 mg/L and salinity averaged 0.15 psu in 1989, however increased to 1.44 psu in 1991 after Hurricane Bob. Pond-wide salinity averaged 0.10 psu in 2016 and is highly dependent on the quantity/ extent of storm over wash events and opening activities. Currently, the pond is highly eutrophic and experiencing significant impairment[3,4,8], with values surpassing both 1989 and historic (2005/2007) values. In 2016, pond-wide TN averaged 0.740 mg/L, higher concentrations (0.780 mg/L) were observed at MP3 located at the northern extent of the pond[4]. Total Phosphate (TP), averaged 0.059 mg/L in 2016, while average pond-wide phosphate was 0.011 mg/L, and was greatest at site MP2, located at the southernmost end of the pond. TP levels exceeded the EPA Total Phosphorus healthy threshold of 0.015 mg/L TP by nearly five times in 2016[4].

According to the 604b study, phosphorus loading to Miacomet Pond was estimated to be 97 kg P/yr, with internal loading, groundwater and surface water inputs contributing[8]. Dr. Wagner indicates that, “Nutrient limitation appears to fluctuate between P and N, with cyanobacteria blooms seemingly coincident with periods of N limitation. Blooms of golden algae (chrysophytes) are more common when P is limiting, but algae abundance is high most of the summer”. The 604b report concludes that “In

Miacomet Pond the estimated internal load is the largest source, but both groundwater and possible surface water inputs may be adequate to support blooms if only internal loading is controlled. Some watershed management may be necessary, although the temporal distribution of internal loading (mostly in late spring and summer) makes that source disproportionately important and its control is likely to provide more benefit than a simple annual accounting of loading would indicate”[8].

Miacomet Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards not being met due to low water clarity (<1.2m safe swimming standard), historic and periodic high fecal coliform and blue-green algae blooms. Water quality standards not being met due to high Total Phosphorus (TP) and high Total Nitrogen (TN) (values over threshold). Aesthetic values and boating are limited due to dense submerged aquatic vegetation and invasive phragmites[6]. Several invasive species have been documented in Miacomet Pond that require attention; Phragmites, Parrot feather, Grass Carp and Koi[6]. Parrot feather management has taken place in Burchell Pond by the Land Bank, however regular monitoring of the main pond basin will be required, as there is evidence of infestations in the channel from Burchell Pond to the main pond[6]. Controlling this invasive plant and educating the public on the threats of invasive species is a priority. There is a mercury TMDL for fish tissue in Miacomet Pond due to atmospheric deposition, which is likely not going to be remediated, due to continued atmospheric deposition. Access to the pond is not well defined, which leads boaters and other pond users to walk over vegetated buffers creating pathways for storm water to directly enter the pond. There is a need for defined access and an information kiosk describing that fish should not be consumed, cyanoHAB possibility and the presence of invasive pond weed.

There is ongoing discussion about the need to ‘open’ Miacomet Pond to the ocean due to concerns about basement flooding and to improve water quality (see Appendix Draft Pond Opening and Modification History). However, due to the disproportionate size of the increasingly developed watershed compared with the size of the pond, groundwater inflow rapidly replaces salt water exchange from pond openings. The Town of Nantucket does not have plans to regularly open Miacomet Pond to the ocean via a man-made channel as is performed with Hummock and Sesachacha Pond. Emergency openings have occurred in the past due to flooding, however these were meant to drain pond water and not allow salt water into the pond (see Appendix Draft Pond Opening and Modification History). This decision is based off of many years of historic management documents which indicate opening benefits were quickly overwhelmed by fresh groundwater inflow to the pond. In addition, based on the flora and fauna currently inhabiting the pond, excessive salt water intrusion would have the negative consequence of freshwater fauna inducing stress and mortality, in addition to potential phosphorus release from sediments due to ion exchange resulting from saltwater intrusion. There is a critical need to manage storm water and control flooding in the heavily developed Miacomet Pond watershed. Miacomet Pond was illegally opened in March 2018, likely to relieve flooding of the roadways and basements from above average groundwater levels experienced in 2018. This opening could produce deleterious impacts to the pond including elevated bacterial levels in the excavated shallow pool, release of previously bound phosphate and increased risk of pond closure due to algal blooms.

IV. Review of Past In-pond Management Techniques

Aquatic Plant Management

Historically Cattails were removed from along the edges of Miacomet Pond, in 1970 a Bulldozer was used to push cattails into ‘earth piers’ in Miacomet Pond.

The Nantucket Pond Coalition has plans to remove invasive Phragmites from the edges of Miacomet Pond in 2019.

Hydraulic Control

- Historically, Miacomet Pond was opened to the Atlantic Ocean, however the pond receives such a high quantity of fresh water from the surrounding developed watershed that any positive influence of openings is quickly diminished as freshwater from the watershed replaces pond water (Appendix Draft Pond Opening and Modification History). "Opening of Miacomet Pond to the ocean stopped over a decade ago and there is little reason to resume that practice, but there does appear to be some surface flow to the pond that must be addressed in loading analysis."[8]
- In 1979
- Pump systems have also employed during flooding, however due to the overwhelming quantity of water in this watershed feeding the pond, the pump was unable to operate fast enough to provide a long-term/ perceivable benefit due to the size of the watershed contributing to the pond.
- The northern reaches of Miacomet Pond were dredged between 1975 (see aerial photos) and 1979 to create a connection with the main body of the pond as part of a real estate development[8] (Appendix Draft Pond Opening and Modification History). This activity turned wetlands capable of natural nutrient remediation into a man-made channel which will require routine management to maintain it from reverting back to its previous state. Costs associated with maintaining this channel should therefore be the responsibility of the individuals interested in such work and not the Town of Nantucket, as it was a private entity which filed the NOI to perform the work. Permit requests to maintain this region will to be assessed on a case by case basis through the Conservation Commission.

V. Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. As such the Town of Nantucket has several long-term management techniques currently underway to protect Hummock Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
  - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
  - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.

- No applications of plant nutrients shall be made:
  - between December 1 and March 1;
  - to frozen and/or snow covered soil;
  - to saturated soil, or soils that are frequently flooded;
  - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more
  - targeted application method, such as a drop spreader;
  - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply
- Non-point Source Management
  - Board of Health Regulations
  - Comprehensive Wastewater Management Plan- State approved 20-year plan
    - Miacomet: Design, 2028 Construction, 2029
    - Somerset: Design 2016 Construction, 2017 (delayed)
  - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
  - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorus containing fertilizer may be used unless a soil test indicates a phosphorus deficiency.
    - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
    - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
    - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
    - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
    - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

VI. Evaluation of In-pond and Watershed Management Alternatives

- Update watershed inspection and upgrade timeline until sewer becomes available (BOH).

- Improve storm-water infiltration in watershed (remove direct sources of runoff from access pathways and asphalt berm gaps (19 on E side of Miacomet), enhance infiltration and vegetated buffers) (DPW/ NRD educational component).

- Entire pond sediment removal to sandy bottom (Rough estimate from NPC $3,677,640, initial investment of $30,000 for site assessment and testing).

- Town owned excavation equipment to facilitate dredging of accumulated sediment (Cat 320 Excavator: ~$300,000, Dredge: ~$500,000, Dump truck for transport to DPW: ~$210,000, Estimate of staff costs: No more than 40 hours per year excavation time, ~20 hrs of dump truck runs (@$27.50/hr=$1650) Approximate total= $822,650 (Excludes taxes/ shipping/ maintenance)

- Possibility for Permeable Reactive Barrier (PRB) for elevated nitrogen concentrations from western edge of pond- ~\$138,000 or \$180/ft^2).

- Re-assess benthic infauna community for improvements associated with nutrient reductions. (NRD, report due April 2018)

- Potential for Town owned harvester to address in-pond accessibility through removal of rooted aquatic vegetation (\$200,000 + \$50,000 in yearly maintenance and operation).

- Bottom-fish removal: This option represents an interesting approach for Miacomet Pond given the presence of Carp and Koi. However, the effect of such management techniques would likely be minimal compared with in-pond phosphorus inactivation, dredging or reduction of land-derived inputs. The most common fishing technique to catch Carp is bow-fishing, which represents a potential opportunity to encourage local anglers to catch and discard large carp and koi which are likely adding to the turbidity and nutrient cycling within Miacomet Pond.

- Pilot project to harvest phragmites.

    - Recent studies in Martha's Vineyard have indicated that harvesting phragmites and pelletizing the harvested material represents a compromise by which both nutrient remediation and view-shed management can be achieved for relatively low costs compared with chemical techniques.

V. Management Recommendations

- Investigate critical water level at which flooding occurs. Consider flood management strategies (TON).
- Vegetation control with Aquatic Harvester (\$25,000 NPC).
- Work with Nantucket Land Bank to control invasive Parrot Feather emanating from Burchell Pond (NLB 2017, NLB/NRD 2018)
    - Determine if better control of Burchell Pond water could be achieved with barriers.

- In-pond bottom sediment provides additional phosphorus for algal blooms, 604b recommended phosphorus inactivation due to potentially toxic cyanobacterial blooms.

    - SOLitude estimates provided by The Nantucket Pond Coalition:

    - Low dose treatment= \$18,050

    - High Dose treatment = \$125,000

- Periodic coliform failures (14% exceedance 2003-2016)
    - Watershed Inspections and Upgrade Regulation (BOH)
- Work with Miacomet Golf Course/ Land Bank to determine if BMP to reduce elevated western inputs is necessary, potential for PRB.
- Improve storm water infiltration in watershed (remove direct sources of runoff from unsanctioned access points/ educational component) (DPW/ NRD)

- Provide access and informational kiosk on west side of Pond (Land Bank, DPW)
- Identify East shore banks where small-scale restoration could be accomplished to intercept storm water runoff. Education component required to be successful.
- Assess stream discharges (NRD)
- Assess groundwater discharges (NRD)
- Initial assessment of benthic infaunal community ($4915-$7915).

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1. 1989 Pond Report, no author.
2. Howes B, and D. Goehringer. 1993. Overview of Nantucket Fresh Ponds 1989-1992. WHOI.
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7. Sutherland, J. and S. Oktay. 2010. Miacomet Pond Water Quality 2009: A Summary of Physical, Chemical and Biological Monitoring. For the Nantucket Land Council, Nantucket, MA.
8. Wagner K. Water Resource Services Inc. (2017). 604b Study of phosphorus sources to Hummock and Miacomet Ponds Final Report.

https://www.nha.org/digitalexhibits/aerialviews/AP1940Web/pages/ap1940_035.htm

Aerial photos. Nantucket Historical Association 1940 and 1975 aerial photographs of upper reaches of Miacomet Pond which reveal no navigable northern channel existed prior to the 1979 development of this section of Miacomet Ave. Also note, Burchell Pond appeared between 1940 and 1975.

Sesachacha Pond

Sesachacha Pond Watershed

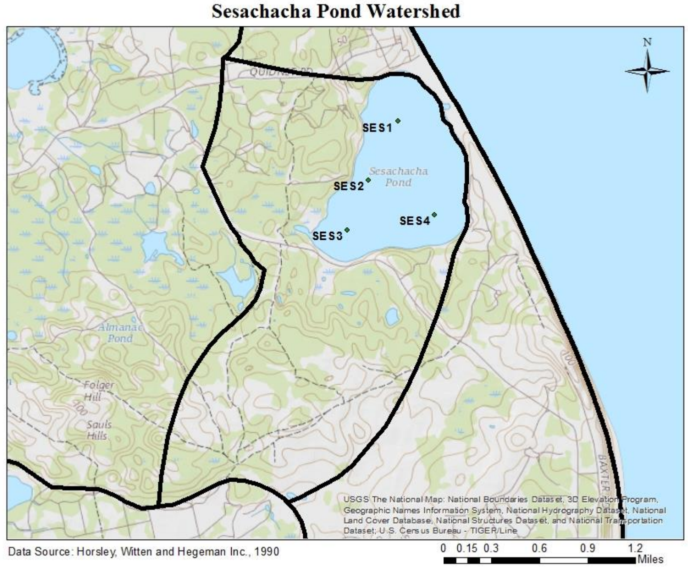

Figure 1. Extent of Sesachacha Pond watershed, as determined by Horsley, Witten and Hegeman in 1990 Nantucket Water Resources Management Plan. Location of water quality sites used for Massachusetts Estuaries Project sampling.

I. Statement of Problem

Sesachacha Pond is a coastal eutrophic salt pond located on the northeast end of Nantucket Island. Sesachacha Pond was formed by the flooding of a kettle pond as a result of rising sea level following the last glacial period approximately 18,000 years BP[1]. Sesachacha Pond covers 255 acres and consists of two deep areas with a maximum depth of 6.6 meters[1]. The watershed to pond ratio is low (3:1) compared to other Nantucket great ponds. Much of freshwater input to Sesachacha Pond occurs via groundwater seepage[1]. While direct small stream inputs to Sesachacha occur from Cains Pond, under Polpis rd and from the southeastern end of the pond, they are usually seasonal and do not carry significant water in the summer. Additional storm water inputs from Polpis road and Sesachacha road occur during heavy rainfall. The pond is non-tidal and the salinity is maintained by periodic breaching of the barrier beach. To a lesser degree saline water enters the pond via salt water intrusion through the barrier beach and storm over wash. Historic pond openings date back to the 1660's, while openings were still commonplace in the 1870's. The northern portion of the pond reveals a Native American site and oyster shell midden, indicating the pond was likely opened by Native Americans to enhance oysters within the pond. In 1981, Sesachacha Pond was opened, however openings were ceased that same year under provisions of the Wetlands Protection Act[2]. In 1983, IEP inc. was hired by the landowner of the eastern shore (where openings take place) to investigate the impact of pond openings on biological and geological resources. No samples were taken as part of this effort; rather it represented a field reconnaissance, review of pertinent reports and discussions with local experts. The biologic findings of this study were that openings had no perceived effect on mosquito control due to the lack of quantitative data on mosquitoes in the region, the benefit to the common oyster and soft shell clam seed populations were not significant enough to warrant opening for this reason alone due to the small size of oysters and clams produced, the opening for finfish enhancement stunted growth of saltwater species due to low salinities and trapped fish within the pond and there could be negative impacts to nesting birds. The geologic findings were that openings negatively impacted the dune, subsequent dune restoration was never conducted, lowered pond level had a negative effect on groundwater quality through saltwater intrusion and expedited septic effluent seepage (it was suggested that septic systems poorly cited close to the pond edge be relocated and updated to combat loading due to septic influences), the rise in pond level is associated with groundwater inputs and rainwater (it was suggested that low lying cottages be stilted to combat flooding issues). Sesachacha was not opened legally by the town between 1981 and 1991, although illegal openings did take place during that time[3] (see Appendix Draft Pond Opening and Modification History). In 1985, the Public Works Department funded a hydrogeologic investigation by Perkins, Jordan Inc to determine the interaction between pond openings, groundwater resources and pond water quality.

Findings from this study indicated that a clay layer exists in the northern region of the pond between elevations 4 and 7 (and may exist under the entire pond), continued closure would decrease the salinity in the pond and surrounding groundwater, and that further development in upgradient areas was not expected to have a significant effect on eutrophication, although it was noted that septic systems cited adjacent to the pond should be addressed on a case by case basis. A subsequent EIR in 1989 indicated that periodic tidal exchange, through openings, was required to stabilize the ecology, since storm over wash would lead to salinity cycling within the system. It was hypothesized that the salinity cycling from over wash and storms would result in highly unstable conditions and impairment of habitat quality within the pond. Sesachacha Pond's MEP report was completed in 2006. Sesachacha's in-pond nitrogen declined below historic concentrations in 2010, 2012 and 2013, leading researchers to hypothesize that successful pond openings were responsible for the improvement. Subsequent sediment tests indicated that Sesachacha's habitat-related health was improving along with its nutrient-related water quality[4]. Unfortunately, restrictions due to protected habitat, narrow permit windows, tide and wind considerations, sand deposition on the inner portion of the barrier beach and coordination between excavation contractors have led to the ponds further eutrophic conditions since sufficient exchange has not been maintained in recent years. Research has indicated that Sesachacha water quality is closely tied to successful pond openings; however, the goal salinity levels (22 psu) have only been achieved 8 times in the past 50 years. Despite planning the openings during the most favorable conditions, changes in wind speed and direction close the pond prematurely. Reports from the 1990's indicated that 75% of the nitrogen available for water column plant growth originates from pond sediment. This finding combined with the high MEP sediment flux values indicates a potential need for sediment remediation. Currently, additional work is being planned for Sesachacha Pond to identify the main sources of nutrients to the pond, ascertain whether nutrient threshold goals are attainable and whether pond openings are providing sufficient flushing for in-pond shellfish and fish species to thrive. This study will lead to the development of a restoration and/ or management plan aimed at improving pond health.

Sesachacha Pond is currently not attaining uses with regards to swimming. Swimming standards not being met due to low water clarity (<1.2m safe swimming standard), some nuisance pond weed and the potential for harmful blue-green algae blooms. Recreational boating in Sesachacha Pond is currently unaffected. However, Sesachacha Pond is closed to shellfishing due to historic bacterial concerns. Water quality standards not being met due to high Total Phosphorus (TP) and high Total Nitrogen (TN). Sesachacha TN exceeded the TMDL of 0.600 mg/L, with 2016 pond-wide averages of 0.978 mg/L. Sesachacha phosphorus far exceeded EPA water quality standards of 0.015, with pond-wide averages of 0.208 mg/L. High TN, TP and iron content entering the system through small streams, represent a distinct concern with regards to phosphorus availability, given the dynamics between iron, salt water intrusion (sulfate availability) and phosphorus release. High phosphorus concentrations, over eight times the EPA water quality standard, pose a distinct blue-green algae bloom threat if salinity levels drop below the primarily freshwater algae salinity tolerances.

There is a need for defined access and an information kiosk describing cyanobacteria bloom possibility and any other pertinent information to the pond. There is ongoing discussion about the efficacy and environmental benefit of the Sesachacha Pond openings and the need for longer duration openings or alternative management techniques. Currently water quality within the pond is tied to successful openings which drain the pond of its high nutrient levels and allow cleaner ocean water to enter the pond. This dilution does not represent a sustainable option for pond management, as it does not address the root cause of the high nutrient concentrations, nor does it remediate those inputs. A more complete understanding of the fish species present in Sesachacha Pond will enable better management of the pond as an anadromous/ catadromous fish resource. Although soft shell clams, oysters, herring, striped bass and eels have been observed in Sesachacha Pond, the salinities presently are not sufficient to allow for these species to grow to marketable size. Therefore, a more thorough understanding of the fish and shellfish species present and their health must be conducted prior to any changes in management of this pond.

II. Management Goals

	Total Nitrogen	Phosph-orous	Total Phosphorus	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
Goals	0.60 mg/L	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

III. Watershed/ Pond Characteristics

According to MEP research and models, most of the locally uncontrollable, un-attenuated nitrogen load to Sesachacha Pond is from direct wet and dry precipitation of nitrogen on the water body surface, while natural surface inputs are the second largest uncontrollable load. Impervious surfaces such as roads direct storm water towards the pond and represent the greatest contribution to controllable nitrogen inputs at 65% of the total nitrogen load, while wastewater from septic systems contributes 25% and fertilizers contribute 10%[1]. Sediment incubations indicated that the shallow regions of Sesachacha Pond were releasing nitrogen to the water column while the deeper basins represented a sink. Overall, there was a net release of nitrogen to the water column, which substantiates the 1991 finding that ~75% of the water column nitrogen is derived from the sediments[1].

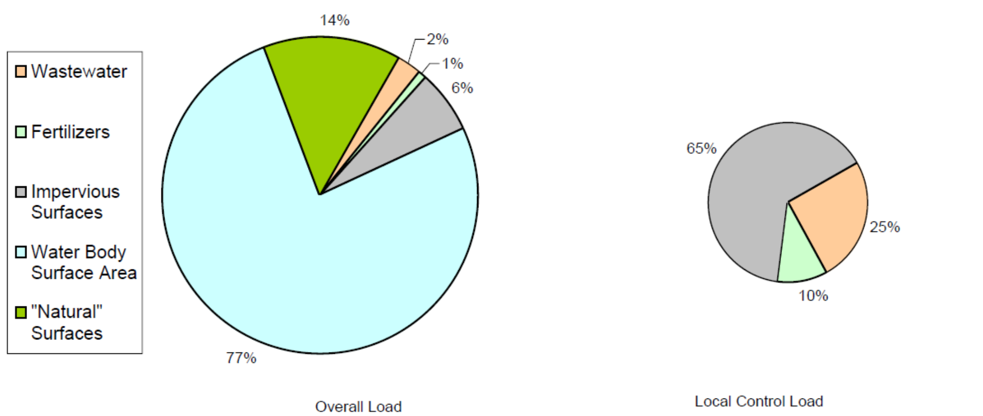

Figure IV-4. Land use-specific unattenuated nitrogen load (by percent) to the Sesachacha Pond System watershed. “Overall Load” is the total nitrogen input within the watershed, while the “Local Control Load” represents only those nitrogen sources that could potentially be under local regulatory control.

Pond Total Nitrogen (TN) in 1985 averaged 0.460 mg/L and was greatest at Station 1 (0.665 mg/L), located in the northernmost portion of the pond closest to Quidnet village[1]. Total Phosphorus (TP) averaged 0.475 mg/L and was greatest at Station 5, located in the middle of the pond (0.560 mg/L)[1]. The salinity averaged 5.675 psu in 1985, 4 years after the 1981 opening[3,4]. Currently, the pond is highly eutrophic and experiencing significant impairment[2,6]. In 2016, pond wide TN averaged 0.978 mg/L, over two times the concentrations observed thirty years ago[6]. TP is not currently measured in Sesachacha Pond, however 2016 average pond wide phosphate values were 0.208 mg/L and were greatest in the southwest corner of the pond, near Cains Pond. The phosphate values measured in Sesachacha were the highest pond phosphate values observed in 2016 and ranged from 7-20 times higher than the phosphate of other Nantucket Great Ponds. Due to the observed levels of phosphate and nitrogen, there is strong algae bloom potential for this system. However, 2016 average pond wide salinity was 11.52 psu which may prevent cyanobacteria species from forming blooms. Sesachacha Pond receives freshwater from groundwater, however small streams and Cains Pond also contribute freshwater. Elevated iron content in inputs are of concern for phosphorus dynamics. The phosphorus load to Sesachacha Pond is exacerbated by the high iron content in the inputs. High iron paired with saltwater intrusion into groundwater, leads to phosphorus release (due to iron binding to sulfate in seawater, thereby releasing phosphorus). This scenario favors cyanobacteria blooms, due to the availability of phosphorus, which is limiting to growth. The current salinity of Sesachacha may be protecting it from cyanobacterial blooms. The 2005 MEP report indicated that the linear increase in total nitrogen concentration is directly related to the rate of net nitrogen release from the sediments, integrated over the entire pond[2]. This rate of nitrogen increase in pond waters was used to calculate a rate of nitrogen increase per square meter across the entire pond per day, from the water volume and bottom area measurements. It was determined that the estimated daily input from Sesachacha sediments during the summer was approximately 18.0 mg N/ m^2/day. This benthic nitrogen flux is similar to Head of Hummock Pond and slightly higher than Long Pond[2].

V. Review of Past In-pond Management Techniques

Hydraulic Control:

The MEP report on Sesachacha Pond indicated that achieving a salinity of 22 psu would facilitate improved water quality within the pond. In the past 50 years, Sesachacha Pond has only achieved a salinity >22 psu 8 times. Recently, 2012 was the last time that salinity >22 psu was achieved in the pond. The opening in 2012 increased the salinity within the pond and lead the Town to investigate the effects that increased salinity and improved water quality had on the benthic infauna of the pond[6]. Samples revealed that the benthic infauna was responding to improving water quality conditions through increased diversity and evenness metrics. However, subsequent openings have not achieved the desired salinity, likely due to sand accumulation and pond opening constraints dealing with time of year restrictions and wind speed/ direction changes.

In the Spring of 2016, the Natural Resources Department began measuring water quality parameters pre and post pond openings to ascertain the effect of openings on pond water quality. Both nitrogen and phosphorus increase steadily throughout the summer sampling season. The Spring 2016 opening duration was 3 days and resulted in a 0.2 mg/L decline in TN and a slight decline in phosphate, although levels were very low (<0.005 mg/L) even before the opening took place. A slight decline in Total Phosphorus also occurred. TN and phosphorus again showed a consistent increase throughout the summer yet began to decline post Fall opening. The Fall 2016 opening duration was 1.5 days and resulted in a large TP and phosphorus decline post closure. TN increased slightly post closure in the Fall. The Spring 2017 opening duration was 7 days in total and required re-opening due to a premature closure from winds. The Spring opening resulted in a 0.2 mg/L decline in TN, and already low levels of phosphorus declined further post pond closure, whereas TP showed a moderate increase post closure. The pond opening water quality measurements indicate that openings can reduce TN levels, especially during the Spring openings, however in-pond TN levels quickly increase to elevated levels during the summer post pond closure. The September TN levels in 2016 were ~0.2 mg/L greater than 2015, indicating that pond openings do not produce a sustained benefit in terms of decreasing in-pond TN levels. In addition, May TN levels were nearly 0.2 mg/L higher in 2016 than 2015. Both May and September TN levels were ~0.2 mg/L greater in 2016 than 2015. Seasonal phosphorus trends indicate that depletion naturally occurs during the winter months, leaving very low levels prior to the Spring opening. This seasonal trend is also evident in the Fall when phosphorus concentrations begin to decline prior to the pond being opened. The benefit of Fall openings to phosphorus concentrations is unclear, as it appears seasonal phosphorus cycling has already begun to decrease the phosphorus content prior to the opening.

IV. Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. As such the Town of Nantucket has a number of long-term management techniques currently underway to protect Hummock Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket's Great ponds are as follows:

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        - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply
    - Non-point Source Management
        - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
        - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorus containing fertilizer may be used unless a soil test indicates a phosphorus deficiency.
            - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration

- To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes
- To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
- To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
- To provide science-based guidance for nutrient management of lawns and gardens on Nantucket

V. Evaluation of In-pond and Watershed Management Alternatives

- Town owned excavation equipment to facilitate pond openings for emergency management and routine clearing of accumulated sediment from opening channel (Cat 320 Excavator: ~$300,000, Dredge: ~$500,000, Dump truck for transport to DPW: ~$210,000, Estimate of staff costs: No more than 40 hours per year excavation time, ~20 hrs of dump truck runs (@$27.50/hr=$1650) Approximate total= $822,650 (Excludes taxes/ shipping/ maintenance) (DPW/ NRD Proposal to CZM grant program)
    - Sediment testing for common limits to dredge disposal (Pre-test $2000, Dredge feasibility study $80,000-$100,000).
    - Contract out permitting required for dredge/ channel maintenance (CLE engineering)
    - Feasibility/ alternatives analysis for openings. (Cost: TBD) (Christine Player CLE Engineering, Town dredge management plan).
    - Investigate feasibility/ benefit of mid-summer opening potential in future.
- Re-assess benthic infauna community for improvements associated with nutrient reductions. (NRD, report due April 2018)
- Cost estimate for Town owned harvester to address in-pond accessibility (TBD- NPC).

VI. Management Recommendations

Short term:

- Add Total Phosphorus (TP) to routine Sesachacha monitoring program (NRD 2018).
- Quidnet Squam Association resident funded investigation into restoration potential for nutrient remediation in Sesachacha Pond (NRD/ Horsley Witten 2018)
- Biologic surveys of vegetation, phytoplankton, fish, shellfish and benthic infauna (NRD/NLC).
- Apply for Coastal Resilience Grant Program, Coastal Zone Management funding for Natural Storm-Damage Protection Techniques (NRD/ DPW/ Horsley Witten 2018).
    - Pond opening equipment
    - Funds to do living shoreline/ oyster castle remediation project (Dependent on results from Spring 2018 Horsley Witten site visit and associated work).

Long-term:

- Re-assessment of Sesachacha watershed using current techniques (Horsley Witten Cost TBD).
    - Finalize Sesachacha on-site septic system inspection and upgrade program (BOH).

- Decrease storm water inputs through active management of roads and impervious surfaces. Redirect storm water from roads back to natural wetland system to the south of Polpis rd. Redirect storm water from Sesachacha rd to wetlands to the northwest of Quidnet village (DPW).
- Study to determine if pond openings can outweigh the eutophication due to benthic regenerated nutrients (NRD/SMAST).

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1. 1989 Pond Report, no author.
2. Howes B., S. W. Kelley, M. Osler, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2006). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Sesachacha Pond, Town of Nantucket, Nantucket Island, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.
3. Sesachacha & Sankaty: Pond opening and erosion on Nantucket's eastern shore by Wesley N. Tiffney, Jr and Clinton Andrews. *Historic Nantucket, Vol 38 no. 1 (Spring 1990), p. 4-6.*
4. P. Brace. 2012. Nantucket: A Natural History. Mill Hill Press; 1 edition.
5. Howes B., S. Sampieri, M. Bartlett, R. Samimy, D. Schlezinger (2015). Water Quality Monitoring and Assessment of Infaunal Health in Sesachacha Pond for Estuarine Resource Management and TMDL Compliance.
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Long Pond

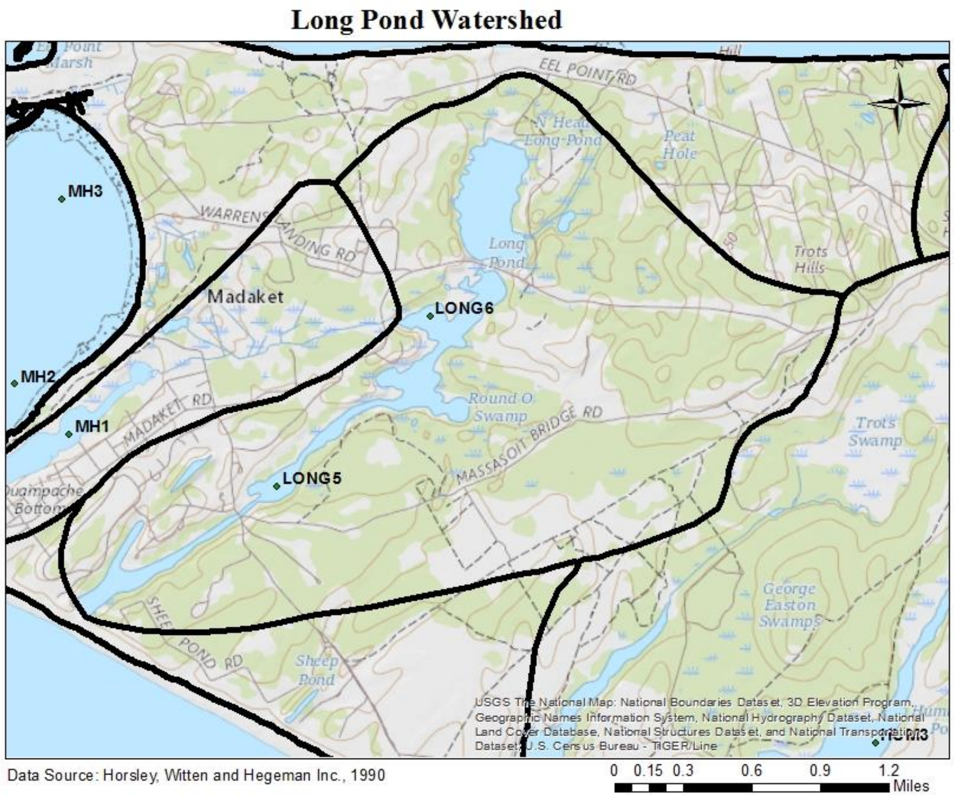


Figure 1. Extent of Long Pond watershed, as determined by Horlsey, Witten and Hegeman in 1990 Nantucket Water Resources Management Plan. Location of water quality sites used for Massachusetts Estuaries Project sampling.

I. Statement of Problem

Water quality standards are currently being met as 2016 represents the second year that the entire pond average TN has been below the secondary TMDL goal of 0.800 mg/L. Phosphorus was below the EPA water quality criteria for lakes and reservoirs of 0.015 mg/L, with a pond-wide average of 0.01 mg/L in 2016. However, Long Pond is currently not attaining uses with regards to swimming, boating and fishing. Swimming standards are not being met due to low water clarity (<1.2m safe swimming standard), historic high fecal coliform and periodic algae blooms. Aesthetic values and boating are limited due to submerged aquatic vegetation and invasive phragmites. Access to the pond is not well defined, which makes boat access difficult for water quality sampling as well as other boat uses. There is a need for defined access and an information kiosk describing that fish should not be consumed and toxic bloom possibility. The culverts connecting Long Pond to the Madaket ditches are undersized and need to be cleaned out/ resized. Very little is known about the aquatic fauna in Long Pond.

II. Management Goals

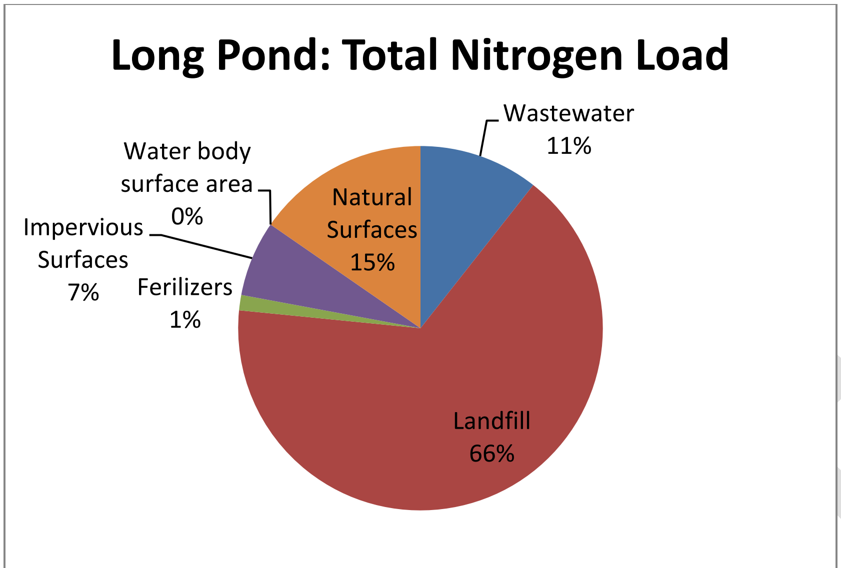
	Total Nitrogen	Phosph-orous	Total Phosphorus	Chloro-phyll a	Clarity	Benthic Infauna	Vegetation	Phytoplankton
Goals	0.80 mg/L (second-ary TMDL)	0.015 mg/L	0.015 mg/L	<10 ug/L	>1.2 m	Diversity >3, Evenness >0.7, low # poor health indicator species	Low nuisance pond weed, swimmable fishable	No cyanobacteria blooms, diverse phytoplankton assemblage

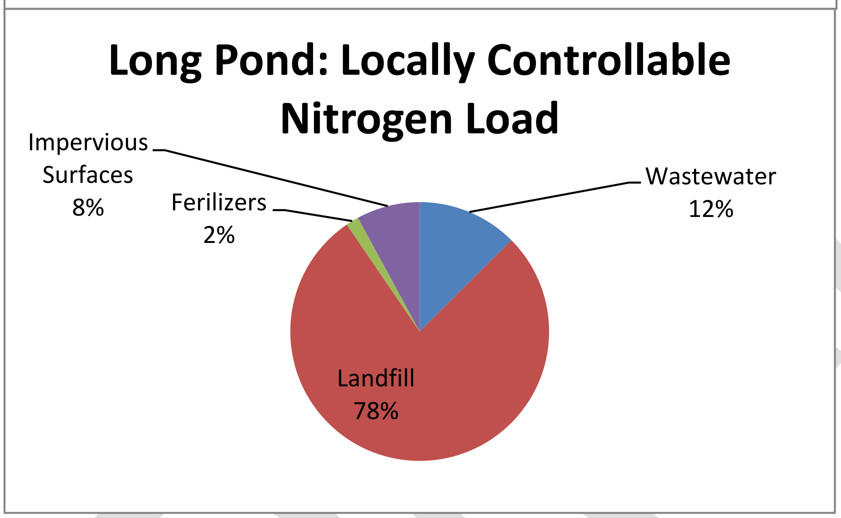
III. Watershed/ Pond Characteristics

Long Pond is a 132 acre tidally restricted brackish pond dominated by fringing wetlands, located to the east of Hither Creek on the western side of Nantucket Island. Long Pond is surrounded by several closely settled residential lots with septic systems and private wells, and the town Landfill is located on the eastern shore. A significant amount of conservation land surrounds the pond, buffering some of the potential land use impacts. According to the Massachusetts Estuaries Project report, the primary locally controllable load to Long Pond comes from the landfill at 78%, while wastewater represents 12%, impervious surfaces 8% and fertilizers 2%. Natural surface inputs represent 15% of the uncontrollable total load[1].

Pond-wide bioactive nitrogen (PON+nitrate+ammonia) in 1989 averaged 0.580 mg/L and was greatest at the innermost pond site (near current site LP5)[2]. Pond-wide phosphate averaged 0.21 mg/L in 1989 and was greatest near present day site LP6. The salinity averaged 4.00 psu in 1989, yet likely fluctuated with the tidal cycle, due to the connection to Hither Creek via the Madaket Ditch[2]. Pond-wide salinity averaged 12.865 psu in 2016 and continues to fluctuate tidally through the connection with Hither Creek via Madaket Ditch[4]. In 2016, pond-wide TN averaged 0.640 mg/L, with higher concentrations occurring further from the ditch connection, at LP5. Phosphorus was below the EPA water quality criteria for lakes and reservoirs of 0.015 mg/L, with a pond-wide average of 0.010 mg/L in 2016[4].

An investigation into Landfill nutrient data was conducted in response to the hypothesis that capping and mining activities at the landfill are responsible for the improved nutrient- related water quality health at the water quality monitoring station adjacent to the landfill in Long Pond. Total Nitrogen (TN) levels at this site indicate an improvement, with TN falling below the secondary nutrient goal (Goal= 0.800 mg/L) for that site since 2014. Historically, the Western edge of the landfill site had been used for animal carcass disposal, which would have contributed to elevated nutrient loads as the carcasses decomposed. Unfortunately, there is no way to validate the historic inputs to the pond, however we can gage whether the habitat is improving because of lowered in-pond nutrient concentrations. In the fall of 2017, habitat related water quality health was assessed through sediment sampling. The animals that live in the sediment (benthic infauna) were compared to historic data to determine if habitat improvement is occurring in conjunction with the TN reductions. The benthic infauna sampling showed improvements in species diversity, almost no stress indicator species found in 2017 and the southernmost station went from no species present in 2003 to 13 species in 2017.





IV. Review of Past In-pond Management Techniques

- **Hydraulic Control**: Long Pond connects to Hither Creek and Madaket Harbor by a ditch dug in 1665 through a cooperative agreement between the island's early European settlers and the Native American Wampanoag Tribe who sought an efficient method of harvesting Blueback herring and American eels spawning and living in the pond, respectively[2].
    - There is no need to manually 'open' the southern portion of Long Pond to the Atlantic Ocean, enhanced flushing can be achieved through maintenance of the Madaket Ditch.
- **Invasive Species Management:** The Nantucket Pond Coalition has facilitated several Phragmites mitigation projects in the Long Pond watershed.
    - **2015-2017 Massasoit Bridge Phragmites Pilot Project:** Madaket Residents Association financed.
    - **2016-2017 White Goose Cove:** CPC Financed.
    - **2017 Southwest shore of Long Pond:** Resident/ abutter financed.
    - **2018 Northwest shore of Long Pond:** Resident/ abutter financed.

V. Review of Existing Watershed Management Techniques

Nutrient inputs are best managed through active land management aimed at decreasing the quantity of nutrients entering ponds from the watershed. As such the Town of Nantucket has a number of long-term management techniques currently underway to protect Hummock Pond from land-derived nutrient inputs. State and town-wide strategies for long-term water quality in Nantucket’s Great ponds are as follows:

- 2010 Massachusetts General Laws Part 1 Title XIV Chapter 111 Public Health Section 5R Definitions; distribution and sale of household cleansing products containing phosphorus; limitations; violations
- 2012 Massachusetts Legislature: *An Act Relative to the Regulation of Plant Nutrients*-
    - Phosphorus-containing fertilizer may only be applied when a soil test indicates that it is needed or when a lawn is being established, patched or renovated.
    - Do not apply plant nutrients to sidewalks or other impervious surfaces. Plant nutrients that land on these surfaces must be swept back onto the grass or cleaned up.
    - No applications of plant nutrients shall be made:
        - between December 1 and March 1;
        - to frozen and/or snow covered soil;
        - to saturated soil, or soils that are frequently flooded;
        - within 20 feet of waterways if using a broadcast method, or 10 feet if using a more
        - targeted application method, such as a drop spreader;
        - within a Zone I of a public water supply well or within 100 feet of surface waters that are used for public drinking water supply
    - Non-point Source Management
        - Board of Health Regulations
            - Local Regulation 53.00: Inspection and upgrading of substandard onsite sewage disposal systems within the Madaket Harbor Watershed
            - Local Regulation 49.00 Madaket Tight Tank Policy
            - Local Regulation 51.00 Town of Nantucket Board of Health Regulations Affecting Madaket.
        - Board of Health Local Regulation 75.00 The Content and Application of Fertilizer for Use on Nantucket
        - Best Management Practices for Landscape Fertilizer Use on Nantucket: Limits to the quantity of nitrogen fertilizer applied per year and no phosphorus containing fertilizer may be used unless a soil test indicates a phosphorus deficiency.
            - To provide landscape professionals and homeowners with information for making environmentally sound landscaping decisions that take Nantucket's unique conditions and natural resources into consideration
            - To promote the protection of water resources while maintaining healthy and vibrant ornamental landscapes

        - To reduce the amount of fertilizer use by promoting cultural practices that help reduce nutrient inputs
        - To offer site-planning guidelines and suggestions for ecological restoration that help reduce island-wide fertilizer-dependent landscapes
        - To provide science-based guidance for nutrient management of lawns and gardens on Nantucket
    - Ongoing landfill capping and mining: With the current mining operation of the landfill, material in the existing unlined cell is removed, sorted, portions passed through a digester and/or recycled. Some materials that cannot be recycled are then shipped off Island and what cannot be recycled or reused are then placed in lined cells, which are then capped preventing contamination to the groundwater. This process reduces the potential for nitrogen loading to the groundwater that ultimately flows into the watershed via Long Pond, Madaket Ditch, Hither Creek and ultimately Madaket Harbor. As this process continues, nitrogen loading is further reduced to the overall watershed. The Town's Annual Water Quality testing shows preliminary results that this mining is reducing the Nitrogen load to Long Pond and together with the removal of on-site wastewater is the solution to meet the TMDL in this embayment area.

VI. Evaluation of In-pond and Watershed Management Alternatives

- Landfill capping, mining and additional nutrient testing of wells (DPW/ Waste Options).

    - Comprehensive Wastewater Management Plan- State approved 20-year plan. The East side of Long Pond falls within the Madaket sewer need area, whilst the entirety of Long Pond falls within the Madaket Water Protection District, as such it has been recommended for sewer service since the 1980's.
        - "In contrast to Madaket Harbor, Long Pond and Hither Creek are well beyond their respective abilities to assimilate additional nutrient loading without impacting ecological health. Nitrogen levels are elevated in these areas with eelgrass beds totally lost from Hither Creek. The result is a need for nitrogen management in the overall system in order to restore the resources and limit future nitrogen loading in the watershed". (CWMP update)
    - The ACO provides property owners with failing on-site systems the ability to defer major repairs as long as their property is located within an approved Needs Area and sewer is proposed in the near future. At the time of this development, Madaket Needs Area was approved to utilize the ACO, which saves the owner from having the expense of designing and installing a major repair/replacement system and then having to pay for sewer. The Board of Health will work with the property owner to find a temporary solution until such time as sewer is available.

    - Local regulation Innovative/Alternative clause if sewer not passed, effective July 2019. (BOH)

- Determine seepage of groundwater from Eastern shore. Assess future PRB possibility- must be cited outside of saltwater intrusion zone (~$138,000 or $180/ft^2)
- Undersized culverts connecting Hither Creek to Long Pond via Madaket Ditch (scope of work and cost associated TBD through Madaket Water Quality Improvement Project 2017-2019).
- Sediment testing for common limits to dredge disposal (Pre-test $2000, Dredge feasibility study $80,000-$100,000).
- Re-assess benthic infauna community for improvements associated with nutrient reductions. (NRD $7242.00, report due April 2018)

VII. Management Recommendations

- Add Total Phosphorus (TP) to routine Long Pond monitoring program (NRD 2018).
- Additional samples to assess landfill nutrient inputs to Long Pond (2017) indicate lower loads than previously estimated.
    - Continue monitoring for Total Nitrogen, Total Phosphorus, landfill area and groundwater movement to track further reductions (CDM/ DPW).
- Landfill loads should be updated using the new landfill area and new groundwater flow data (CDM/ DPW).
- Linked-embayment models should be updated to reflect landfill management activities and ascertain current land management requirements to achieve TMDL goal in Hither Creek sentinel station (SMAST/ Applied Coastal: April 2018) (NRD).
- Aquatic flora and fauna surveys (NRD/NLC).
- Herring/ diadromous fishery assessment (NRD/ NLC).
- Continue with Long Pond Phragmites work (NPC).

Works Cited:

1. 1989 Pond Report, no author.
2. Howes B, and D. Goehringer. 1993. Overview of Nantucket Fresh Ponds 1989-1992. WHOI
3. Howes B.L., J. S. Ramsey, E.M. Eichner, R.I. Samimy, R. Acker, D.R. Schlezinger (2010). Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Madaket Harbor and Long Pond Estuarine System, Nantucket, Massachusetts. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.
4. Howes B., S. Sampieri, M. Bartlett, R. Samimy, D. Schlezinger (2017). Water Quality Monitoring and Assessment of the Nantucket Island-Wide Estuaries and Salt Ponds Update 2016.
5. Howes B, S. Sampieri, R. Samimy (2017). Technical Memorandum- Updated Benthic Infauna Survey- Long Pond.

Appendix

Draft Pond Opening and Modification History

March 19, 1859 Hummock and Miacomet let out as the first herring of the year were caught through Madaket Ditch.

1881- Proposal to construct a canal from the southernmost end of Clarks cove across the fields to Long Pond to facilitate herring passage to Hummock Pond (no information about whether this was completed). Also, discussion of sinking a 40ft long 'trunk' with gates across the opened regions of Sesachacha and Miacomet that could be cleared of sand to allow for more successful openings.

1882- Management of Madaket Ditch.

May 13 1893- Fishermen 'let out' Miacomet Pond to scoop-net herring

1896- Sesachacha opened- Blue Fish came in.

May 26, 1906- Miacomet opened.

April 10, 1909- Sesachacha and Hummock opened.

Spring 1912- Madaket Ditch was cleaned and maintained.

February 27, 1915- Sesachacha Miacomet and Hummock planned to be opened, 'unusually full this season'. Sesachacha foul condition after not having been opened in 10 years. Opened and closed overnight due to winds, required re-opening.

January 1, 1916- Hummock and Miacomet opened.

April 10, 1920- Sesachacha, Miacomet and Hummock opened by selectmen. Farm land and properties had been flooding more so than they had in years and citizens petitioned the selectmen to open them. Polpis Rd needed repair and the Polpis Rd committee was eager to open it.

1922- Sesachacha, Miacomet and Hummock likely opened as two students wrote about the 'opened areas' in the beach in the Historical association essay contest.

May 12, 1923- Sesachacha waters interfering with the Polpis Rd. construction and voted to be opened.

May 23 1931- Miacomet opened to the sea- herring caught.

April 8, 1933 Sesachacha opened (opening close to Quidnet rather than the beach region).

August 29 1931 Miacomet opened

May 28, 1932- Sesachacha opened, pond so full that water was backing up into the mosquito ditches.

June 4 1932 Article "Answering questions is part of our job- What did they open Sesachacha pond for? The pond was too high. The opening was made to let the water run out to the sea, so as to drain the marshes and surrounding territory that has been ditched"

April 8, 1933- Sesachacha Hummock and Miacomet opened

~1937- Sesachacha opened (likely Hummock as well but no indication in archived articles)

March 1939- Hummock opened

1940- Discussion about a permanent steel pier to maintain Sesachacha opened.

May 9 1942- Sesachacha opened

1944 Hummock opened

1948- Sesachacha and Hummock opened

1953- Hummock opened, but Mr. Bartlett and Gardner were not in favor as they used the water for irrigation and couldn't use it once it became salty.

1954- Sesachacha opened

1958- Hummock opened

1959- Miacomet opened

1960- Miacomet opened

April/ May 1962- Hummock, Miacomet and Sesachacha Ponds opened

Thursday March 7 1963 Lester Ayers Jr. mosquito control dept. backhoe used to legally open Miacomet. Newspaper article indicates that the standing water on Washington Street behind Hatches gas station used to drain after Miacomet was opened but it did not drain this year, so it was suggested that drain pipes be installed to take care of the flooding (suggested Town warrant article).

August 3, 1967. Miacomet illegally opened.

Dec 24 1969- Opened Miacomet Pond to drain water to remove cattails from East and West side of pond. Also removed cattails from northern area of Hummock and Long Pond which had experienced excessive Cattail growth. Cattails were suspected to influence the water table and were actively managed. Food planted for waterfowl, to deter them from feeding at the landfill, greatest quantity of birds observed at Miacomet Pond.

1970- Cattail issue, studies suggest removal as they silt in the ponds, waste water and contribute to access issues. 7000 feet removed from Miacomet, Hummock and Long. Bulldozer used to push cattails into 'earth piers' in Miacomet and Hummock Ponds so that the public could fish without trespassing. 49 miles of drain ditches cleared/ maintained and Miacomet, Hummock and Sesachacha opened. Discussion to install sluice gates for water management in ponds.

1971- Cattail issue threatens the ponds by overgrowth, water uptake and issues with access. “North Head of Long and Hummock will be dead ponds within 10 years if something isn’t done about the cattail growth”.

May 17 1973- 26 inch corrugated pipe installed through barrier beach of Miacomet to allow for water drainage. Hummock Pond also had a pipe installed. Conservation Commission report- “We are at a critical point in Nantucket’s history. Our actions **now** will determine whether the islands natural resources will be protected for the enjoyment of future generations or will be destroyed by overdevelopment. Active citizen participation in the Commissions work will be welcomed”

1975- Sesachacha, Miacomet and Hummock opened, access issues due to high water.

1976- Miacomet, Sesachacha and Hummock opened

May 2, 1977 Opened Miacomet and Sesachacha, Norwood Farm Realty Trust plan for 16 lots on Miacomet Ave.

May 11, 1978- Miacomet, Sesachacha and Hummock. Due to high groundwater the ponds were opened earlier than usual and stayed open longer. 88% increase in notices of intent at the conservation commission. “Weed control program” Cattail removal, Long pond.

July 6, 1978- “Based upon a study of Miacomet Pond by Wes Tiffney, the Conservation Commission modified the NOI application filed by Norwood Farm Trust. The Trust proposed to dredge cattails in the northern end of Miacomet Pond, an area 1200 feet in length by 100 feet in width. Tiffney is concerned with the protection of that swamp which is rich in flora and fauna. Tiffney suggested that access paths be cleared on the western bank by dredging only a narrow channel. The channel would be suitable for passage by small rowboats and canoes. The rest of the swamp would be left in-tact” Norwood farm trust

November 26,1980- Notice of intent- Norwood farm trust to dredge upper Miacomet Pond. May 27, rescission of the Norwood Farm Trust plan- notice of public hearing.

October 29, 1981- “Norwood Farm Trust had been granted an order of conditions to dredge the smaller portion of Miacomet Pond to make it more accessible to the larger part of the pond. After dredging was completed, however, the smaller body of water completely emptied into the main part of the Miacomet Pond. After making a field inspection the Commission decided to discontinue the Trusts notice of intent to build until the smaller portion of the pond is restored”.

1981- Was the last year Sesachacha was opened before Wetlands Protection Act led to discontinuation of openings.

April 14, 1983- Sesachacha and Miacomet vote to open May- Article entitled “To open or not to open: The Sesachacha question remains” Town Biologist Ken Kelley wants to keep opening “widespread growth of green algae which he attributed to sewage entering the pond from flooded septic systems”. Continual lowering of salinity was also cited as cause for the demise of the pond. Coastal Geologist Jeff Benoit of the Executive office of Environmental Affairs felt that “opening the pond was not consistent with the mandates set forth by the Coastal Regulations of the Wetlands Protection Act of 1978” Once the selectmen went through the proper channels to file a Notice of intent with the Department of

Environmental Quality Engineering (DEQE), DEQE came back stating they required plans by a professional engineer or registered surveyor, clearly showing location and scope of work, a report by a qualified biologist addressing impact on pond environment including mosquito habitat shellfish habitat and documentation of land ownership. Opposition had been registered by the legal counsel of the owner of the barrier beach Rosemary Hall Evans. She previously allowed the openings but began to worry about erosion that had been occurring on her land, "I would ask the Selectmen to address the problem of restoration of the dunes which have been so terribly eroded and have caused, and continues to cause, severe financial loss to my property. The landowner funded the IEP report which found that "The pond is a poor environment for shellfish and it's not good for finfish, either. It's up to the homeowners to take care of their own cottages," and he said that the owners should raise their houses instead of lowering the pond" High water up to the houses and the sewage systems weren't working. Miacomet was also discussed as to its need for a DEQE file number for the emergency opening due to flooding.

July 19, 1984- "In most cases reasons for opening ponds center largely around flooding and the erosion it causes (Except Sesachacha which still has a large albeit dying oyster population). The breaching of the barrier beaches in in direct conflict with the wetlands protection act. During deliberations Hummock and Miacomet continued to be open for emergency flood management. "How can we sit here and watch our homes fall into the pond" Town added Squam, Reed (east of Capaum) and Clark Cove to the desired opening list.

July 16, 1984- Land Council opposes openings- all the ponds differ and there are often good reasons not to open the ponds. John Roe

October 24, 1985- Concom denies pond opening applications because of Wetlands Protection Act.

April 28, 1988 Proposal to Dredge upper Miacomet Pond. (ConCom letter indicates it was performed in 1986 and paid for by abutters "and having collaborated with my neighbors on Miacomet Avenue in having the North end of Miacomet Pond dug out in 1986, at a cost to us of $20,000 which we paid as private citizens to convert a melly, eutrophic, mosquito-ridden swamp into a real pond")

Conservation Commission
Thursday April 28, 1988
Selectmen's Hearing Room
7:30 PM

Applicant: Karen Schwenk et al.
Location: Upper end of Miacomet Pond
Proposal: Proposal to dredge and to contruct a dam on Miacomet Pond in order to restore water level adjacent to applicants' houses. Applicants feel that dredging further south in the pond caused the water level to drop.

June 18, 1992 July fourth opening. Steve Scannel- tried for years to use civil disobedience to convince the courts to rule on the issue to no avail.

1993- Sesachacha opened "Part of the reason the channel won't stay open is the inner bar which formed when the pond stayed closed in the 80's". "The opening would be handled (as in past years) by the

DPW." Article 67- Local control of pond openings, Home Rule petition. Hummock and Sesachacha regularly opened twice per year from 1995 to present (2018).

May 4, 1994- Town opened & closed Miacomet to alleviate flooding for the first time in 15 years by Harbor Marine and Shellfish Department. Emergency permit for Army Corps of Engineers, "Strictly to lower the water level, closely monitored to ensure the salt and fresh water did not mix" The relief quickly dissipated as groundwater filled the pond a foot after the opening.

August 11, 1994 Officials fear health risks from Miacomet pond opening. Selectmen rules the shallow pool created from the opening should be filled in as it was unsanitary (warm breeding ground for bacteria).

Oct 31, 1996- Normal rainfall 43 inches, 52.69 thus far that year. Unseasonably high rainfall, the pumps used to maintain lower water levels in Miacomet Pond could not keep up.

November 11, 1996- Miacomet illegally opened.

Dec 5 1996- Natural opening of Miacomet Pond. "The ponds freshwater ecosystem could be irreparably damaged by the uncontrolled openings". Bruce Perry ConCom

February 13, 1997- Vote to open ponds 2x per year. Miacomet opened six times over the last 6 months. "Development is contributing to its oxygen loss"

March 6, 1997- Heavy equipment used to illegally excavate a watering hole on the Land Bank Burchell property, no permits or permission obtained for the excavation.

May 12, 2003- Miacomet opened by the Town due to a favorable BOS vote.

May 26 2005- Miacomet Pond illegally opened. Sunfish and yellow perch stranded. "The fish shouldn't be affected because they will flee into the freshwater wedge however the eggs could be affected by desiccation". Notes about the koi issue as well (koi are invasive and actively disturb bottom sediment allowing more surface area to be exposed for nutrient release).

June 9 2005 Miacomet opened illegally open 4 days.

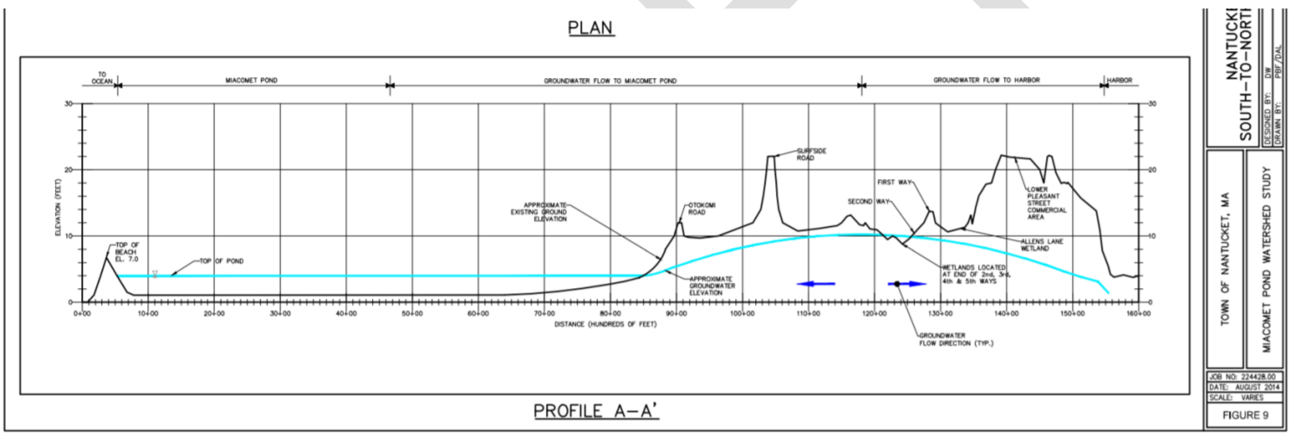
May 6 2010- Vanessa Raab and Andy Lowell- Suggest to open Miacomet a couple hours before low with west south west wind. "Increased development (Nantucket Ice, Elementary school, skate park)- don't allow water to be taken up"- Fronzuto

"The file on opening Miacomet is thick and full of written testimony from environmental agencies and concerned citizens and the file really leans towards not opening the pond on anything other than an as needed basis for flooded roads. I'm very sympathetic to the flooded basements but this pond is a 25 to 1 watershed to pond ration compared to Sesachacha and Hummock which are 1.5 and 1" Dave Fronzuto.

September 2014- Miacomet Pond Watershed Study https://www.nantucket-ma.gov/DocumentCenter/View/7131

“1998 – 2001 – Development South of Marble Way and Northwest of Bartlett Road • 1998 – 2001 – Development Northwest of Somerset Road • 2005 – 2008 – Development Northeast of Marble Way and South of Somerset Road • 1998 – 2001, 2007 – Development North of Boynton Lane and South of Bartlett Road • 1998 – 2001, 2008 – Development East of Miacomet Avenue and South of Otokomi Road”

“Woodard & Curran used the data in the report to complete a cross section of Nantucket Island from South-to-North to analyze what impacts, if any, Miacomet Pond has on upstream groundwater levels. This cross section can be found in Figure 9, and shows the elevation of groundwater relative to the surface elevations through the low-lying geological formation bisecting the island. The section clearly shows high point in the groundwater surface. Groundwater flow to the south of the high point, or flow divide, contributes to Miacomet Pond whereas flow north of the divide contributes to Nantucket Harbor. The elevation of the groundwater in the HWH report indicates at the divide is approximately elevation 10. This elevation is approximately six feet higher than the elevation of Miacomet Pond, indicating a positive flow gradient to the pond. As such, Woodard & Curran concluded Miacomet Pond does not contribute groundwater flow upstream, but rather, is a receiving water body for all groundwater within the watershed”



Profile of land and groundwater elevations from Miacomet Beach through pond to Nantucket Harbor, indicates peak of groundwater elevation exists between Surfside road and Second way. Note blue arrows which indicate groundwater flow directions (Woodard and Curran. 2014. Miacomet Pond Watershed Study, Nantucket, MA. W&C, Dedham, MA).

March 27, 2018- Miacomet illegally opened, stayed open for ~10 days. Received salt water, subsequent tests indicate low clarity and high alkalinity indicative of algal growth. Beach requires maintenance to avoid summertime bacterial issues in shallow pond where opening was dug.

	In progress										
	Priority										
	Long-term- (CWMP or need for Capital Funds)										
		Benefit time period	**Permitting Cost**	**Equipment Cost**	**Yearly operating budget**	**One time Cost**	**Hummock (upper 50 acres)**	**Miacomet (28 acres)**	**Sesachacha (255 acres)**	**Long (132 acres)**	**Harbors**
Watershed Management	**Sewer Hookups (re-direct and treat to a higher level than title V Septic)**	Indefinite, requires maintenance					$34226000 (N) $24,866,000 (S)	$20,762,000.00	BOH Inspection/ Upgrade/ IA	$42,650,000	Infill regions and BOH I/A
(Nutrient Reduction)	**Fertilizer BMP**	Indefinite					X	X	X	X	X
	Transfer of Development Rights (conservation restrictions)	Indefinite					X	X	X	X	X
	Educational Programs	Indefinite					X	X	X	X	X
Nutrient Remediation (In-system)	**Phosphorous Inactivation** High Dose Low Dose	11 years 1-5 years	$30,000			$4400/acre $1100/acre	X $220,000 $55,500	X $125,000 $18,050	N/A Brackish	N/A Brackish	N/A Brackish
	Sediment Removal & Disposal	~50-100 years	$30,000			$30/ $yard^3$	$8,100,000	$3,677,640	24,000,000	12,000,000	Dredge plan, add Head of Harbor
	Hydraulic Control (Pond Openings/ Emergency infrastructure protection)	Depends on ability to maintenance dredge, current benefit is dependent on successful opening	CAT 320 Excavator with trailer 10 Wheel Dump truck **Total**	$300,000 $210,000	$10000 (issues with maintaining proper timing and re-open schedule) $10,000 **$520,000**	$10,000/year	X X X*	X X*	X X X*	X X*	X *
	Dredging (sediment)	1-5 years	Suction Dredge **Total**	$500,000	$10,000 **$510,000**		X	X	X	X	X
	Dredging (plants)	1 season of growth, removal of plant derived nutrients	Harvester **Total**	$200,000	$20,000 **$220,000**	$15,000/pond	X	X	X	X	
	Shellfish Restoration	Long-term					N/A	N/A	X	TBD	TBD
	Floating Wetland	1 season of growth, removal of plant derived nutrients			$25/ft2				X		
Nutrient Remediation	**Permeable Reactive Barrier**	Dependent on materials used	When elevated loads are known from one section of shoreline- PRB's can help to remediate those inputs locally			$180/$ft^2$	X (potential W edge)	X (potential W edge/ golf course)		X (E edge if landfill groundwater shows need)	X (unknown currently)
(in groundwater)	**Stormwater Management**	Long-term, requires maintenance							X		
	Living Shoreline	Long-term, requires maintenance			$50-100/ foot						
	Constructed Wetland	Long-term, requires maintenance	$20,000					X		X	X
							*Operation cost higher due to quantity of sediment= unknown (need sediment mapping)	*Operation cost higher due to quantity of sediment= 91,200 $yard^3$	*Operation cost higher due to quantity of sediment= unknown (need sediment mapping)	*Operation cost higher due to type of sediment= unknown contamination, need sediment mapping & clean out culverts.	Unsure of feasibility of using this suction dredge in Harbor